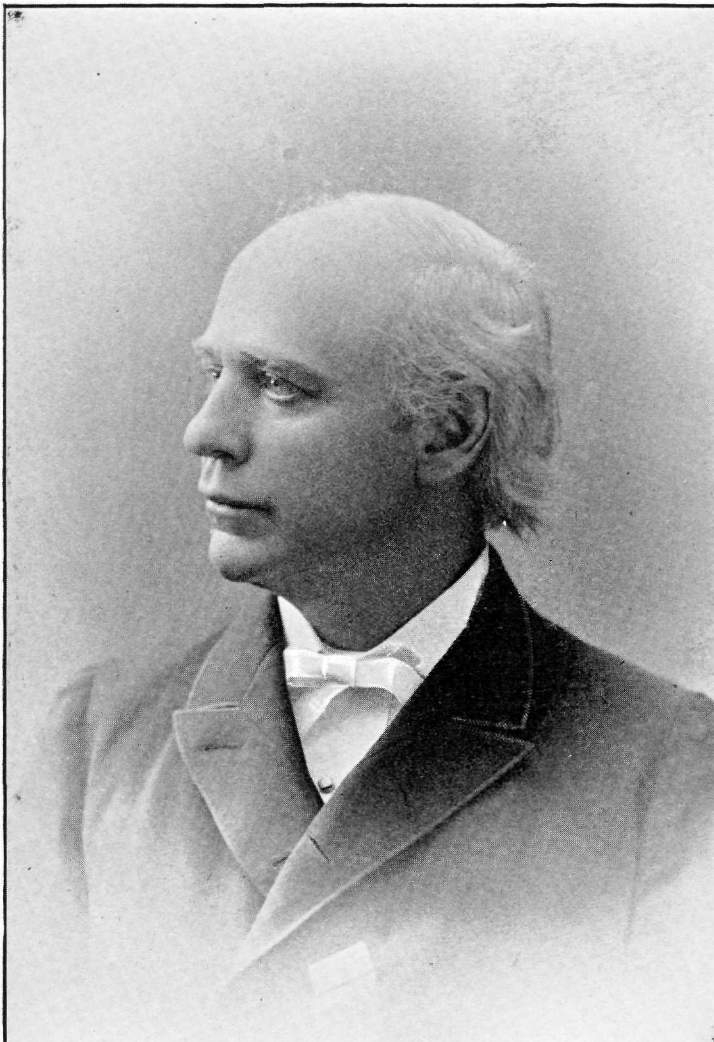
WHAT GEOLOGY OWES TO THE MINER OF COAL.

BY PROF. EDWARD ORTON.

I have long recognized the fact that the science of geology owes a great debt to the coal miner, and it has seemed to me appropriate to such an occasion as this, to recognize and acknowledge the debt. I wish this evening to call your attention, as representatives of the coal mining interest, to some of the points in the history of geology, in which the influences and contributions derived from such sources are most clearly shown.

1. Coal mining had a great deal to do in the laying of the very foundations of the science of geology. There is nothing in geology more thoroughly fundamental than its great doctrine of the orderly succession of the rock formations which constitute the surface of the earth, the doctrine, viz., that strata occur in a regular and unchanging order. The crust may be deformed by faulting, folding, overturning or erosion and certain formations may be sometimes found where we would at first sight have least expected them. But when the facts are all in, there is in every case a new confirmation of the great doctrine that every stratum has its own place and order in the scale, from which it never departs.

We have learned to recognize and distinguish the many strata that compose a geological section by the fossils they contain and the order in which they occur. On the testimony of these fossils and this order we decide many points with absolute confidence; nor are our judgments reversed by experience. For example, if the claim is made that tin ore is found in the undisturbed rocks of southern Ohio, we answer promptly and with perfect assurance that the claim is an erroneous one, and that it is made either in ignorance or in fraud, or in both. We would give the same answer as to the claim for the existence in Ohio of gold, silver, the diamond or the ruby. They are not to be found in the normal scale. Take another example. Black shales are often associated with coal seams, but when any one declares that the black shale of North Columbus, Worthington, Chillicothe or Delaware, is the blossom of coal, and that a good prospect exists of finding this precious mineral in paying quantity by



PROF. EDWARD ORTON.

proper exploration, we answer at once that the claim is without foundation; that it is impossible that coal seams should occur in this range of rock. In fact, all such claims at the present day arise from what is fast becoming unusual ignorance. Those that make them certainly do not "know as much as the law allows." We draw a boundary on the map of the State and we know that it is vain to look outside of it for workable deposits of coal. If any apparent exception is found, it will in reality prove a most striking confirmation of the rule.

All this is settled and established for all intelligent men. We have grown up in the conviction of the regularity of the stratified deposits of the crust, and we scarcely know when we began to hold these views regarding them. In fact, it is hard for us to conceive that men ever held any different attitude in regard to the strata from that which we now hold. And yet, of all the millions of men that were living in the world one hundred years ago, there was but one, so far as we know, that entertained these modern views, and he held them but tentatively and imperfectly. He had caught a glimpse of the great truth and became thoroughly engrossed in working it out and in putting the facts in their true and permanent order. This man was a mining engineer of his time. He called himself a "mineral surveyor." He had not a really aristocratic name, nor was he able to boast of high or noble lineage. He was the son of an English farmer of Oxfordshire, and his name was William Smith. His father's name was John. William Smith was endowed by nature with wonderful powers of observation; having eyes, he saw, and having ears, he heard, and in these respects he was a marked exception to the general law. He began life as a land surveyor. His first independent work was done in 1791 in Somersetshire, in Southwestern England. He was then twenty-two years of age. His principal inquiries were directed to the coal formations of that district, and the mining locality with which he was immediately connected, is known to us as High Littleton. His work was continued through 1792-3, and as the result of it all he says: "My subterraneous survey of these coal veins with sections which I drew of the strata sunk through in the pits, confirmed by notion of some regularity in these formations. But the colliers would not allow of any regularity in the matter of the hills above the red earth which they were in the habit of sinking through. But on this subject I began to think for myself." His work at High Littleton was continued through 1792-3, and the result of it all was a clear hold on the structure of a coal field. He saw the facts so clearly that he was impelled to share his knowledge with those around him, and began forthwith a model on a true and proportionate scale of the strata involved. He found these strata all dipping to the southeast, and he saw how this uniformity of dip would necessitate the outcrop of the several strata in parallel bands, rising successively into the air, to the northwest. In other words, in 1793, William Smith had formed a distinct and definite notion of a settled order of succession of the geological formations of Southwestern England, of their continuity of range at the surface, and of their general declination to the eastward. He had demonstrated the truth of these facts in a limited area, and what he needed was an opportunity to test the hypothesis on a larger scale. The opportunity came about thus:

The first step toward the development of a coal field in England in those days was the construction of a canal for the transportation of the output of the mines, just as a railway branch is now the first step towards the opening of a coal mining property. When the Somersetshire coal canal was finally ordered by Parliament in 1794, William Smith was made its engineer, and the company judiciously decided, before entering on the work of construction, to send a committee of two of its members, who were practical coal operators, together with their young engineer, to examine the various systems of water transportation that had already been opened in other parts of the kingdom. Of this journey, William Smith says, 'This was joyous intelligence to me. I wished to travel, for I foresaw that the truth of my system must be tested far and wide before it could be generally known or appreciated. No journey purposely contrived could have better answered my purpose than this.' It covered nine hundred miles of travel through England from south to north, and back again, through the central portions of the kingdom. It was made by chaise or carriage, with plenty of opportunities for halting whereever occasion required, and it was on this journey, as he says in the later years of his life, 'The interminable labor of working out the truths of the science of geology was begun, for it plainly appeared that it was to become a system of experimental philosophy which would finally embrace the whole surface of the earth.'

For six years Mr. Smith was in the employ of the Somerset Coal Canal Co. He had charge of the construction of the canal. In the rock sections, necessitated by this work, he came to see 'that each stratum had been successively the bed of the sea and contained in it the mineralized monuments of the races of organic beings then in existence.' He finally reached the conclusion 'that each stratum contained fossils peculiar to itself and might, in cases otherwise doubtful, be discriminated and recognized from others like it.' On January 6, 1796, he wrote: 'Fossils have long been studied as great curiosities, collected with great pains, treasured with great care and admired like playthings because they are pretty, and this has been done by thousands who have never paid the least regard to that wonderful order and regularity with which Nature has disposed of these singular productions and assigned to each class its peculiar stratum.'

These commonplaces of modern geology were the most startling novelties and paradoxes of the day of William Smith. But, you ask, what had geologists been doing or thinking of before his time? I answer, there were no geologists before his time. The word 'geology' was almost unknown one hundred years ago, and the reality of the science as now understood, was but dimly conceived, and that only by a single individual. There were professors and philosophers in plenty, who worked out in their closets theories of the structure of the earth, or rather of how it ought to have been made, but these theories had the most vague and distant connection with the facts to the explanation of which they were directed. But had not men recognized stratified rocks and fossils before this time? Yes, certainly; even the true order for limited areas had occasionally been laid down, but the facts they had so bound up with their own fictions that nothing of value could possibly come from their discussions. They were busy in constructing images, the heads of which might be the gold of fact; but the feet were the miry clay of their own speculations; and the images, consequently, had no coherence nor viability. A breath created them and a breath could destroy. Some conceived the earth as made up of stratified rocks to the very center, believing these beds were arranged in the order of their specific gravity, as if they all had settled from a watery menstruum. And fossils? As already stated, fossils were often gathered as curiosities. Sometimes by the idle, sometimes by the studious and sometimes by the pious. By many they were counted as freaks of Nature; as tricks played upon us by a creative power. Those that believed them to have been originally living forms counted them all as remnants and proofs of the deluge of Noah. The flood played a great part in the geological theories and speculations of this time. It is to the credit of our mineral surveyor, the engineer of the coal company, that he kept all his inquiries and discussions entirely free from a theological basis. He believed the world was rational and intelligible and he gave his best powers to understanding it. He seems to have ignored the records of Genesis, but how he escaped coming into collision with its defenders it is hard for us to see. He was the first to prove a universal order of the stratified rocks; he was the first to make the fossils which they severally contain the witnesses of their age. He found that these fossils furnished the means of determining the relative dates of the strata in which they were formed. I repeat what I said at the beginning, if there is anything that is fundamental in the science of geology, it is found in just these two principles, the establishment of which we owe to William Smith, the coal mining engineer.

One other illustrious service geology owes to this 'mineral surveyor." He was the first to construct a geological map of any part of the earth's surface. The labor of his life was expended in preparing and at last publishing, 'a map of the strata of England and Wales.' To accomplish this, he gave the best years of his life; traveling over the entire kingdom, principally on foot; from quarry to quarry, from county to county, expending upon the work every penny he could earn by his admirable training and qualifications as a practical engineer. The work found him poor and kept him so. Its fulfillment was finally accomplished in 1815. His map was the first of that great series of maps which every civilized government in the world now feels bound to make of its territory, as an indispensable guide to the proper development of its resources.

I ought not to leave upon your minds the impression that William Smith was devoted exclusively to your calling. All through his life the discovery and development of coal mines made a leading branch of his occupation; but he also had a deep and sustained interest in other departments of geological inquiry and especially in soils and water supply as related to the underlying rocks. These subjects divided with coal his chief practical activity. But high above all these bread-winning labors, by which he could easily have grown rich, stood the great task which he had set for himself, viz., to determine the order of the stratified rocks that make the surface of the earth, and to discover the means of establishing their relative ages wherever found. For these results, he endured hardship and poverty, and to a certain extent, the light esteem of the multitude. In the end, however, his work came to universal recognition and honor. Even the government furnished to his declining years a moderate pension that saved him from dependence or want; while the scientific societies of the world vied with each other in bestowing honor on our mining engineer. He lived to see geology become a household word, and its great generalizations growing into the staple of everyday thought and speech. None now disputes the title which the geologists of England gave to him and by which he must always be known henceforth, viz., the Father of Systematic Geology.

2. Leaving William Smith and the foundations of geology, I call your attention in the second place, to the confirmation and

extension of geological knowledge that has been derived from the work of the miners of coal. Coal is beyond question the most important mineral that the crust of the earth contains, the most necessary to human development and progress. The search for it and the working of it when found have been carried forward on a scale proportionate to its value. We have opened more mines for coal than for any other mineral, and we have followed it deeper and have worked it through galleries of immensely greater length and area than are to be found in any other mines. From these extended and multiplied explorations geology has derived a knowledge of the order and character of the strata that justly inspires the highest confidence.

In innumerable instances predictions of the presence of coal in untested territory and the depth at which it would be found have been ventured on and the predictions have been fully verified.

We make use of facts and principles derived from this experience in our search for water, oil, gas or salt. But mark the difference between these two lines of exploration. The coal seam must be reached by a shaft, nineteen to twenty feet in diameter, laboriously sunk by pick and blast and every inch of which is fully open to the most careful scrutiny. The oil well, on the other hand, is but six or eight inches in diameter and the formations traversed by the drill are brought up to us in a pulverized state, the chemical composition of which can be determined, but any minute knowledge of structure or fossil contents is obviously impossible. Evidently there is a vast difference between a coal shaft and an oil well as to what they can give the geologist.

3. In the third place, the coal miner has enriched the science of geology by several invaluable contributions. For example, he has made known to geologists the most remarkable flora or development of vegetable life of all past time. The vegetable world presumably began in the simplest forms, in one-celled plants, perhaps microscopic in size, that floated in the waters of the primeval ocean; but in accordance with some law of progress and development which Divine wisdom has implanted in the frame of Nature, these one-celled plants are succeeded by ever higher and more complex forms; group after group, stage upon stage, until at length a period came when plant life had climbed about half way up the long ladder of ascent that separates the earliest from the present flora. It was this middle range of the vegetable world that attained such a wonderful development in carboniferous time, a development that has never been equaled since. This flora consisted of ferns, scouring rushes, club mosses, in the greatest variety and profusion, and a more sparing distribution of coniferous trees, pines,

araucarias and the like. For this flora, all things were ready. Perhaps there was a somewhat larger percentage of carbonic acid in the atmosphere than at present. If this were true, two important results would have followed from it; viz., vegetation would find more abundant food, and the temperature of the earth's surface would be much higher and more equable than it now is. Perhaps the sun was at a hotter stage than it now shows. There were large areas of land lying but little above the level of the sea, and this arrangement would be favorable to a moist atmosphere. At any rate vegetation grew as it never grew before and perhaps it has never since equalled this prolific development. Let me point out a few of the more familiar forms of the carboniferous flora as represented on the charts which I have placed here (Here followed an extemporized description of the leading groups of coal plants, illustrated from charts).

All these the coal miner has brought out of their deeply-buried repositories. He has given us root and stem and branch, wood and pith and bark, leaf and spore and fruit of these ancient trees, and has enabled us to understand them almost as well as if they were growing on the surface of the earth to-day.

We have further learned that of this wonderful growth only a remnant was saved in the coal seams. Coal consists mainly of those parts that could longest resist open-air decay. It is the hardest or at least the most enduring tissues that enter into the structure of this precious mineral. Sir William Dawson declares that every foot of coal cost the growth of one hundred generations of these ancient forests. The sigillaria contributed, as a rule, only their bark. The tree lived out its decades and its centuries and fell at last to the surface of the swamp. There, its inner wood decayed, passing back into the atmosphere; but the bark holds on and keeps up appearances until other trees fall upon it and crush the hollow shell into a flattened column made up of bark alone. The lepidodendra yields like results, but they make another and an all-important contribution besides. Their nearest representatives to-day are, as I have already shown, the club mosses, or lycopods found abundantly in the mountains of Western Europe. The reproduction of this group of plants is effected by spores, and the latter are produced in almost incredible quantities. These spores make an article of commerce and find their way all over the civilized world. They constitute the lycopodium of commerce and are used by the druggist and the pyrotechnist. The druggist avails himself of their resinous nature for coating the pills which he makes, rendering them easier to swallow thereby. In fireworks, their rapid-burning qualities are found useful. But if our present lycopods, growing on the mountains of Sweden, and attaining a height of five or six inches above the ground can yield lycopodium so abundantly that it can be sold on the opposite side of the globe for 60 or 70 cents a pound, what should we have a right to expect, or rather what could we not expect of the giant lycopods of the carboniferous age that grew a hundred times as high. and a hundred times as large as their degenerate representatives of to-day. They must have covered the ground beneath them to the depth of several feet with their annual shower of slippery spores. These spores are durable to a high degree. They are not wet by water and so resist decay. One shower would last until it was covered by another. Entire seams of coal in some instances and definite parts of seams in other cases have been found to be made up of these lycopod spores. Perhaps the peculiar qualities of one coal seam as distinguished from another will be found connected with the kinds of vegetation from which each is derived. It has been found that some of the choicest English coking coals are characterized by a large percentage of these lycopod spores. As a rough generalization of my own, I venture to suggest that the seams derived principally from sigillaria bark are openburning. This mode of origin is eminently characteristic of the upper part of the middle Kittanning seam of the Hocking valley, as I have already shown. As this seam is traced eastward, this feature disappears or is at least far less conspicuous and at the same time there is a notable increase in the coking quality of the coal. This problem of the coking quality of coal is not insoluble. It will surely yield to the microscope of the petrographer and to the balance of the chemist.

Finally, the structure of a coal field as made known by the miner has given to the geologist the clearest and most convincing evidence of the instability of the earth's crust that is to be found in the entire range of his science. Every coal seam was formed at the ocean level. This relation is essential. And thus we come to see with Darwin that what we delight to call terra firma is, in reality, "the type of instability." There are times and seasons in the history of the crust when these movements become more frequent, when oscillations are in order. Long intervals of rest at such times are essential to the growth of a coal field. To the generation of such a field three conditions are indispensable: (1) an abundant growth of vegetation, (2) at the level of the sea, and (3) oscillations of the crust. Both were united in the carboniferous age not only for this continent but in Europe and Australia as well. In other portions of the world and even in our own country in the Rocky mountain region, coal fields have been developed at other points in the geological scale, but the same conditions can be traced in all—to the very existence of the seam. The sea must be at hand to cover the vegetable accumulation, to seal them up with appropriate deposits, to compress them so as to work the strange transformation of vegetable tissue into coal. If left uncovered above the surface of the sea, they would be worn by erosive agencies and slowly wasted by the action of the atmosphere.

But in the heart of a coal field we find one seam above another. Two, three—a half dozen seams may be found in a single hill, each one standing as it does for a long period of growth, centuries, milleniums, is covered at last through a movement of subsidence which lets in the sea with ts burden of silt or sand. Occasionally the sea holds quiet possession of the area long enough to roof over the buried coal swamp with a layer or stratum of limestone that requires for its growth a period comparable with that required for the growth of the coal seam itself. We have several examples of this in our Ohio scale.

I have called your attention to what the coal miner has already done for geology, but let us not imagine that his services are no longer needed, that all is known in regard to the field of his labors that we need to know. I love to believe that much that we have already gained is solid knowledge, that it is "firmly fixed no more to move," but no one sees more clearly than I, how fragmentary and incomplete it all is, after all. Geology is but a hundred years old. She has made splendid use of her first century, but give her another century like "morning risen on mid noon" and who shall set a limit to what she will have accomplished in working out the grand history that it is her province to trace?

Members of Engineers Mining Institute, I beg you to hold to the traditions of your profession, and see to it that every new feature of your calling is duly reported so that it too can become a part of the growing knowledge of the world.

The reading of Dr. Orton's paper was listened to with close attention and followed by prolonged applause, after which it was given to the Institute for discussion.

MR. HUGHES: I do not want to take any more time than is allowed to visitors—

SECRETARY HASELTINE: You are one of us.

MR. HUGHES: Well, to one of us, then, from a foreign State —but I want to say that this address of Professor Orton's is the finest entertainment I have ever received at a meeting of mining engineers in my life. At school I never could get myself so entirely in the hands of the person addressing me as I have been able to do in the case of the gentleman who addressed us to-night. If I had had that lecture made to me twenty years ago, I would have been a far smarter man than I am to-day. But the seeds this gentleman has dropped into us ought to develop a thirst for geology, which as the professor says is in its infancy, and in the next decade ought to make us not only interested students, but enthusiasts. I never had it more purely, sweetly put before me than to-night.

MR. KANE: A question, please. Mr. Hughes has covered my sentiments with regard to the pleasure of the entertainment I have derived from Professor Orton's paper. I have that appetite Mr. Hughes speaks of and would like to have it satisfied to some extent by something more from Professor Orton. I understand the superabundant growth of the carboniferous age, then the necessary contiguity to the sea, but I did not catch the meaning of the oscillation which the professor speaks of, which is necessary for the formation of coal. Perhaps I was a little sleepy when he covered that point and did not catch it; but I would like, if he has covered it, to have him repeat it for my special benefit, and I am sure it will not do the rest any harm.

PROFESSOR ORTON: The vegetation must have a cover, and how can it get it without going down? When another seam comes above it there has got to be a downward movement, an upward movement or rest.

MR. KANE: Mr. Chairman, I can understand the probability of the vegetable growth and also the feasibility of the necessary closeness to the sea and inundation by the sea, but as to the third factor, oscillation—what caused that?

PROFESSOR ORTON: That is a longer story and I do not think it would be well to begin on it to-night. I would like to have you for a student, sir.

MR. HUGHES: I would like to ask if you consider anthracite coal (I presume you do) a much older period of formation than the bituminous.

PROFESSOR ORTON: The anthracite formation was caught in the making of the Allegheny mountains and was metamorphosed by that process.

MR. JENNINGS: I would like to ask what causes the grain of the coal, the jointing of the coal?

PROFESSOR ORTON: That is another topic that would require considerable more time to discuss than I think worth while to consume now, and I think I will have to dodge it.

SECRETARY HASELTINE: I have no question to ask, for I always feel as if we should save our esteemed member as much as possible; and still when he favors us with one of these interesting, profitable talks, we become so hungry for further knowledge that we impose on his generosity and strength. I always have said and believed that the Institute owes more of what it is to-day and what it has accomplished to Dr. Orton than to all the rest combined. I once heard our esteemed friend, Mr. Jennings, say that he talked to us until he made geologists out of all of us. And I think it is the feeling among the members who have been connected with the Institute for a number of years, that what insight we have into geology has been derived from Dr. Orton; and what we have read has been caused by a thirst of knowledge inspired by him. I think perhaps Mr. Hughes has said what I would like to say much more pleasantly than I am able to; but I want to say to Dr. Orton that we feel that he is really the Father of this Institute, and that it would have been gone and perhaps forgotten years ago if it had not been for his interested kindness and enterprise. I wish to move a vote of thanks be tendered him for this delightful entertainment he has afforded us this evening.

(Motion seconded and unanimously carried.)

PRESIDENT ORTON: We will next be favored with an address by Professor Ray of the Ohio State University. He will name his subject for himself.

Professor Ray spoke as follows: